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OPTIMIZATION OF THE CONTROL ALGORITHM FOR LOADING GLASS BATCH INTO A GLASS MAKING FURNACE

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An algorithm for optimal control of glass-batch loading into a glass making furnace is examined; it takes account of the possible use of partial portions of scrapped batch. The admissible changes of the category for a mixture consisting of quality-standardized batch with a partial portion of scrapped batch are determined from the computational results. When the category is changed, the glass batch is redistributed over the width of the loading bin.

Key words: control, loading, batch.

The quality of prepared batch in production is evaluated according to five categories depending on the deviations of the mass content of the proportioned materials [1]. The admissible deviations of the chemical composition of the batch, depending on the duration of these fluctuations and the averaging capacity of the glass-making furnace, must not exceed the average daily deviations 0.5 – 0.6% (category 3) and their limiting value is 0.20 – 0.25% (category 2) with average five-day fluctuations of the content of the components in the glass batch [2].

When the mass content of one component deviates by more than $\pm 1\%$ from a prescribed value the batch is regarded as scrap and, following technological protocol, must be removed from the glass-making process for recycling.

For this, various mechanisms (reverse conveyors, throw-off plows, and switch bags), which at a signal from the control system signaling scrapped batch according to the proportioning results remove the bad batch into an intermediate hopper or bucket, are provided in proportioning-blending lines and line which transport the batch into the glass making furnace.

In practice, single substandard batches are not always used; sometimes, if the proportioning error for one component does not exceed $\pm 3\%$, they are used by adding partial portions of scrapped batch to a proper batch, transported to a loading hopper of the glass-making furnace in subsequent cycles of the proportioning?blending line (PBL). As a rule,

neither the category of the glass batch to which is scrapped mixture added nor the magnitude of the deviations of the mass content of low- and high-melting components in the scrapped batch is taken into account in such cases. The batch adjustment operation is performed manually and is not monitored by an automatic system that controls the production process and the loading of the glass batch.

We have proposed a method for controlling differentiated loading of batch into a glass making furnace that makes it possible not only to use scrapped batch but in individual cases to improve the category of the batch obtained and adjust the distribution of the batch over the width of the loading bin of the furnace by mutual compensation of the positive and negative deviations of the components in the scrapped and proper batch.

This is accomplished as follows in the proposed method of control.

The components of the glass batch which have been proportioned in the batchers of the weighing line are loaded into the blended, where they are mixed. Depending on the proportioning error for each material the PBL control system determines the category of the running batch and the particular component (low- or high-melting) whose proportioning error caused batch quality degradation. A batch belongs to category 1 for deviations of the mass content of the main components from ± 0.0 to 0.2% , category 2 for ± 0.21 – 0.40% , 3 for ± 0.41 – 0.60% , 4 for ± 0.61 – 0.80% , and 5 for ± 0.81 – 1.00% .

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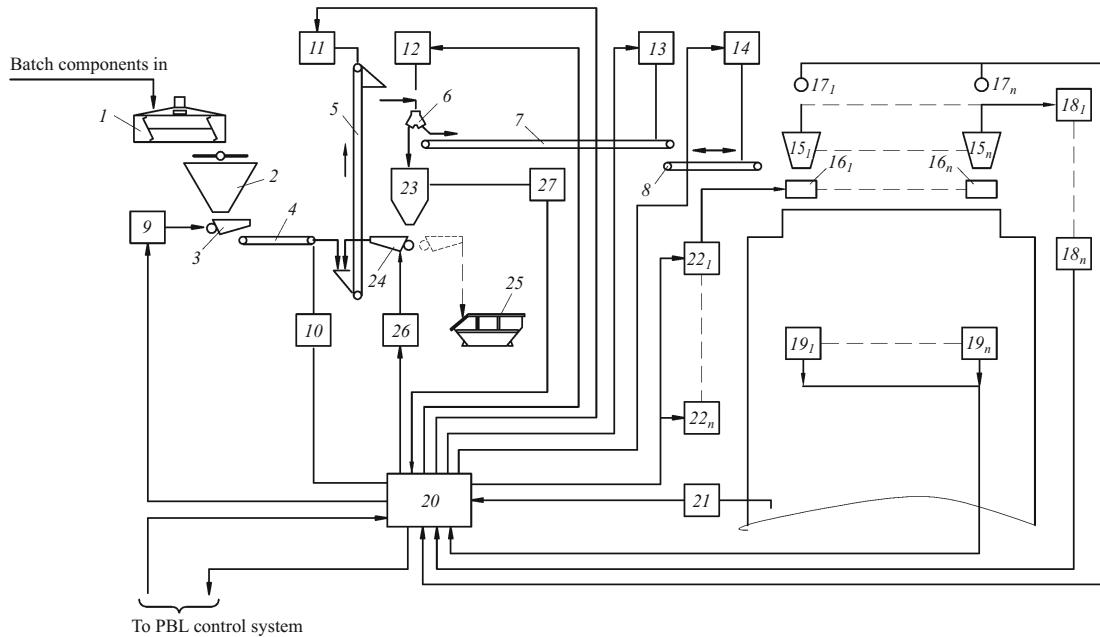


Fig. 1. System controlling the loading of batch into a glass-making furnace.

After the batch category has been determined and the prescribed blending time has elapsed, a command from the PBL system opens the unloading slide of the blender 1 (see Fig. 1) and the ready batch is dumped into the unloading hopper 2.

If a category 1, 2, 3, 4, or 5 batch was obtained as a result of proportioning, then this batch is fed into the hoppers 15₁–15_n (maximum $n = 12$) of the batch loaders 16₁–16_n by means of the vibrating feeder 3, conveyor 4, elevator 5, switch bag 6, gallery conveyor 7, and shuttle conveyer 8, all controlled by the blocks 9, 10, 11, 12, 13, and 14, respectively. The position of the shuttle conveyer 8 is fixed by the corresponding sensors 17₁–17_n, and the level sensors 18₁–18_n monitor the filling of the loader's batch hoppers.

If the batch portion being loaded belongs to category 1, then this batch is distributed over all hoppers 15₁–15_n uniformly depending on their filling level. However, if the batch portion transported from the blender 1 to the shuttle conveyer 8 belongs to category 2, 3, 4, or 5, then according to the algorithm controlling the differentiated load [3] the batch distribution is set taking account of the temperature gradient in the glass mass in the loading bin of the glass making furnace. The temperature field of the glass mass over the width of the loading bin is measured by means of the temperature sensors 19₁–19_n, signals from which are fed into the microprocessor control block 20. Ordinarily, the temperature distribution of the glass mass reaches its maximum value along the axis of the furnace and its lowest values along the edges at the side walls of the loading bin.

In accordance with this control algorithm, which takes account of the temperature distribution of the glass mass in the loading bin and the category of the glass batch, category 2 or 3 batch is redistributed in the hoppers corresponding to

the zones of the loading bin with the average glass-mass temperature. Category 4 and 5 batches with the maximum relative increase of the content of low-melting components are loaded into the peripheral zones of the loading bin while category 4 and 5 batches with the maximum relative increase of the content of high-melting materials are fed along the center of the load front.

The batches from the hoppers 15₁–15_n are loaded into the furnace depending on the glass-mass level measured by the level meter 21; the actuators 22₁–22_n, which are controlled by the block 20, actuate the batch loaders.

If the mass content of one of the batch components deviates by more than $\pm 3\%$, the scrapped batch is dumped, by means of the switch bag 6, into the scrap hopper 23 and the turning vibrating feeder 24 loads it into the bucket 25 for re-use.

However, if the deviation of the mass content of one component resulting in scrap during the proportioning operation is in the range ± 1 –3% (this range can be narrowed), then the scrapped batch remains in the bunker 23 to be loading as part of the regular batch into the glass making furnace.

To assess the possibility of used scrapped batch the PBL control system determines the deviation of the mass content of one of the components which has resulted in scrapped batch and additional calculations are performed in the following manner.

It is known that when the mass content of certain components changes in the glass batch by $\pm 0.1\%$ of the prescribed value the density of the glass, which affects its optical properties, changes substantially in the fourth decimal place [4]. This is completely unacceptable for glass used in the electronics industry and undesirable for automobile windows and

construction glass. Consequently, a deviation of $\pm 0.1\%$ in the mass content of one of the components is taken as the maximum value for the mass of a partial portion dispensed from the hopper 23. The number N of partial portions is determined from the relation

$$N = \delta/0.1, \quad (1)$$

where δ is the proportioning error of the component which results in scrapped batch.

The mass $M_{p,p}$ of a partial portion is calculated from the expression

$$M_{p,p} = M_{t,p,s}/N, \quad (2)$$

where $M_{t,p,s}$ is the mass of the total portion of scrapped batch removed from the blender.

For example, for a total batch portion of 3000 kg and proportioning error 1% the number of partial portions is $N = 1/0.1 = 10$ and the mass of a partial portion is $M_{p,p} = 300$ kg.

The upper value $\pm 3\%$ of the admissible deviation of the mass content of the component of the scrapped glass batch, which can be mixed in partial portions to the total portion of the quality-standardized batch, is calculated as follows. The maximum duration of a cycle consisting of preparing and unloading batch from the blender is approximately 8 min, and the total batch storage time must not exceed 240 min (for longer times the batch loses its properties). For this reason, the maximum number N_{max} of partial portions blended into the proper batch must correspond to the number batch unloading cycles over 240 min:

$$N_{max} = 240/8 = 30.$$

Substituting this value into the relation (1) we obtain that the maximum deviation δ_{max} of the mass content of one of the components of the scrapped batch is

$$\delta_{max} = N \times 0.1 = 30\% \times 0.1 = 3\%.$$

After the amount and mass of the partial portions have been determined, the scrapped batch is added in partial portions to the proper batch in each subsequent cycle of loading batch into the glass making furnace. This is accomplished by means of the turning vibrating feeder 24 controlled by the block 26. The vibrating feeder 24 is actuated simultaneously with the belt conveyor 4, which feeds the batch into the elevator 5. The capacity of the vibrating feeders 3 and 24 is chosen so that the times required to unload complete and partial portions would be approximately the same. The mixture of the proper batch and partial portion of scrapped batch is transported by the elevator 5; then, the conveyors 7 and 8, by means of the flow switch 6, deliver the batch to the hoppers of the batch loaders. The mass sensor 27 monitors the mass of each partial portion.

We shall now give two examples of how scrapped batch is used in the process of loading batch into a glass making furnace.

Example 1

The prescribed mass of a batch portion unloaded from the blender is 3000 kg.

The prescribed amount of sand in the batch is 1800 kg or 60%.

The actual deviation of the sand mass content from the prescribed value is $+ 1.2\%$ (the batch is considered to be scrapped).

The next batch portion consists of category-1 batch with deviations of the sand mass content from the prescribed value by $+ 0.1\%$.

We determine from the relation (1) the number of partial portions of scrapped batch:

$$N = 1.2/0.1 = 12.$$

We now calculate the mass of one portion of the proper batch taking account of the sand proportioning error 0.1% :

$$M_{t,p,p} = 3000 \text{ kg} + 1800 \text{ kg} \times 0.1\% = 3001.8 \text{ kg} \\ (1.8 \text{ kg} — \text{sand proportioning error}).$$

Next we determine the mass of the complete portion of the scrapped batch taking account of the sand proportioning error 1.2% :

$$M_{t,p,s} = 3000 \text{ kg} + 1800 \text{ kg} \times 1.2\% = 3021.6 \text{ kg} \\ (21.6 \text{ kg} — \text{sand proportioning error}).$$

Now we use the relation (2) to calculate the mass of a partial portion of the scrapped batch:

$$M_{p,p,s} = 3021.6/12 = 251.8 \text{ kg}.$$

The sand mass in the complete portion of the proper batch taking account of the proportioning error $+ 0.1\%$ is

$$M_{sand} = 1800 \text{ kg} + 1800 \text{ kg} \times 0.1\% = 1801.8 \text{ kg}.$$

The sand mass in the partial portion of the scrapped batch taking account of the proportioning error 1.2% is

$$M_{sand p.s} = (1800 \text{ kg} + 1800 \text{ kg} \times 1.2\%)/12 = \\ 1821.6/12 = 151.8 \text{ kg}.$$

The total sand mass in the blend of a complete portion of the proper batch and a partial portion of the scrapped batch (taking account of the proportioning error) is

$$M_{sand b} = 1801.8 + 151.8 = 1953.6.$$

The total error in proportioning the sand in the blend will be

$$\delta_{t,s} = \frac{1953.6 - (1800 + 1800/12)}{1800 + 1800/12} \times 100\% = 0.18\%,$$

where 1953.6 is the sand mass in the blend taking account of the proportioning error; $(1800 + 1800/12)$ is the sand mass in a blend with zero proportioning error.

Therefore, the total deviation of the sand mass error in the blend increased and was + 0.18%, which corresponds to a category-1 batch. The batch category and the batch distribution over the width of the loading bin do not change (the batch is distributed uniformly over the width of the furnace's loading bin).

Example 2

The prescribed portion of batch unloaded from the blender is 3000 kg.

The prescribed amount of sand in the batch is 1800 kg or 60%.

The actual deviation of the sand mass content from the prescribed value is - 2.0% (the mix is considered to be scrapped).

The next portion of the batch is a category-4 batch with deviation of the sand mass content from the prescribed value + 0.65%. The batch must be loaded into the zone of the loading bin with the maximum temperature.

Now we use the relations (1) and (2) to calculate the number of partial portions of the scrapped batch:

$$N = 2.0 / 0.1 = 20$$

and their mass

$$M_{\text{p.p.s}} = (3000 - 1800 \times 2\%) / 20 = 148.2 \text{ kg.}$$

Next, just as in the example 1, we determine that the total error in proportioning the sand in the blend is

$$\delta_{\text{t.s.}} = \frac{1999.9 - (1800 + 1800 / 20)}{1800 + 1800 / 20} \times 100 \% = 0.52\%,$$

where 1899.9 is the mass of the sand in the blend of a complete portion of the proper batch and a partial portion of the scrapped batch, taking account of the corresponding sand proportioning errors + 0.65 and - 2.0 %.

According to the computational results, the total deviation of the sand mass content in the batch decreased and was + 0.52%, which corresponds to a category-3 batch. The batch category improves and the distribution of the blend over the loading bin must be adjusted (the batch must be loaded into a zone of the loading bin where the temperature assumes its average value).

In summary, the implementation of the optimized algorithm for controlling batch loading makes it possible to decrease the raw materials losses and increase the thermal uniformity of the glass mass by improving the quality of the glass batch and by providing a more rational distribution of the batch over the front of the loading bin.

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